EFFECTS OF AN ACUTE BOUT OF EXERCISE OF COGNITIVE FUNCTION IN ADOLESCENT ATHLETES

By

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Acknowledgments

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Abstract

Exercise is associated with physical, psychological, and cognitive health. The purpose of this study is to examine the effect of a single bout of exercise performed in the morning on cognitive function in adolescent athletes. Participants (*N*=14) were competitive swimmers aged 12-17 years. CogState Research software was used to assess various aspects of cognitive function. The Two Back (TB) Task measures attention and working memory; the Groton Maze Learning (GML) Test measures executive function and spatial problem solving; and the Continuous Paired Associate Learning (CPAL) Task measures visual learning and memory. All tests were administered before and after two experimental conditions on separate days within the same week. The exercise condition consisted of a vigorous swim practice for 60 minutes. The sedentary comparison condition consisted of watching an instructional swimming video for 60 minutes. TB results indicated a borderline significant time x condition interaction ($p=.06$). No change from pre- to posttest was seen in the swim condition (ES=0.05); a medium improvement from pre- to posttest was seen in the sedentary condition (ES=0.49). GML results indicated a borderline significant interaction ($p=.07$). A small decrease from pre- to posttest was seen in the swim condition (ES=-0.16), while a small to medium improvement was seen in the sedentary condition (ES=0.39). CPAL results indicated no significant interaction ($p = .30$). A small decrease from pre- to posttest was seen in the swim condition (ES=-0.22), while a small to medium improvement was seen in the sedentary condition (ES=0.34). Watching an instructional video for 60 minutes resulted in small to medium improvements in several aspects of cognitive function, while no changes in cognitive function were seen after 60 minutes of swim practice. The cognitive demands of swim practice may fatigue participants so that no improvements in cognitive function result consequent to physical activity.

Introduction

Over the past decade, research on the effects of sports and exercise on adolescent development and brain function has increased. Current research suggests a connection between exercise and cognitive function (Biddle & Asare, 2011). One variable that has been overlooked in previous studies of cognitive function and exercise is the time the exercise or practice is held. While most high school practices for sports are held after school, an increasing number of high school teams, especially swim teams, have begun incorporating morning practices into their schedule. These practices, held as early as 5:00 AM, give coaches an extra hour or two of instructional time with their athletes per week.

With dreams of seeing their athletes compete at the collegiate level, an increasing number of high school coaches have begun scheduling morning practices for their teams. While these are becoming more prevalent in increasingly younger athletes, the effects of these practices on cognitive function still remain a mystery. Parents are rightly worried about potential health risks that may be associated with the lack of sleep at the expense of increased practice time, especially when kids as young as 12 years old are attending these practices. Lack of sleep has been linked to increase behavior problems and reduced cognitive function (Blunden et al., 2005). Adolescent athletes may be up hours before their peers rise to begin getting ready for school, sacrificing sleep hours in order to train. This loss of sleep due to practice attendance may negatively impact academic performance (Fredriksen et al., 2004). The effect of early morning exercise on cognitive function has not been fully explored, and questions remain about the effect these bouts of exercise have on brain function.

Review of Literature

Several factors, domestic and cultural, have led to severe reductions in the amount of daily physical activity youth receive (Lee et al., 2007; Tomporowski et al., 2008). Data show that upwards of one-third of adolescents do not achieve adequate levels of exercise each day (HealthyPeople.Gov, 2015). Even more unsettling is knowing that adolescent obesity is indicative of obesity later in live, with 80% of overweight adolescents becoming obese adults (Eaton et al., 2007; Flegal et al., 2001). Childhood obesity is a contributing factor in the decreased life expectancy seen in younger generations, marking the first time in US history that children may life shorter lives than their parents (Kamijo et al., 2012).

Before one can observe the relationship between exercise and cognitive function, is it first important to define key terms. Exercise is a term that is often used interchangeably and incorrectly with physical activity. Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure. Exercise is physical activity that is planned, structured, and repetitive (Caspersen et al., 1985). Cognitive function, or executive function, is defined as a collection of mental processes that require concentration and thought, while instinct and knee jerk reactions are inefficient or not possible (Diamond, 2013).

Acute Exercise and Cognitive Function

Hogan et al. (2013) investigated the relationship between acute exercise and cognitive function in adolescents. Thirty adolescents, ages 13 and 14 years, participated in the study. Subjects were divided into two separate categories, fit or unfit. Subjects then participated in two conditions, a 20 minute bout of exercise on an electrically braked stationary cycle ergometer and a 20 minute rest period. A movie was shown during both conditions. Cognitive function was measured using a modified Eriksen flanker task. The results of this study showed that the fit cohort performed better on the flanker task than the unfit cohort. Although the fit group had higher overall performance on the cognitive assessment, the unfit group benefitted more from an acute bout of exercise than the fit group. The researchers concluded that both overall physical fitness and acute bouts of exercise may improve cognitive function in adolescents.

Hillman et al. (2013) also explored the effects of moderate-intensity cardiovascular exercise on cognitive function. In this study, researchers used a modified flanker task to assess cognitive performance of 40 children following 20 minutes of treadmill walking and 20 minutes of seated rest. Researchers saw small improvements in cognitive function following the exercise condition, and little to no effect on cognitive function following the rest condition. These results further demonstrate the benefits of a single, acute bout of exercise on adolescent cognitive function and overall brain development.

Chang, Labban, Gapin, and Etnier (2012) conducted a meta-analysis on the current literature regarding the effects of exercise on cognitive function. The purpose of this study was to analyze the existing literature and reveal the specific moderators that affect the interaction between cognitive function and exercise. Seventy-nine studies were included in this analysis. Results indicated small, positive benefits in cognitive function across three separate exercise conditions: during exercise, immediately after exercise, and after a short (10-20 minute) break following exercise. Chang et al. concluded that small benefits to cognitive performance can be seen after acute bouts of exercise.

While several studies point to small improvements in cognitive function, the specific effects of acute exercise on adolescent cognitive function has yet to be fully explored. Furthermore, the relationship between acute, early morning exercise and cognitive function in trained, adolescent athletes is not well understood. The purpose of this study was to begin to explore the effects of acute, morning exercise on cognitive function in adolescent athletes.

Methods

Subjects

Fourteen competitive swimmers at a local year-round swim club were recruited using flyers and word of mouth (Appendix B). All subjects had more than one year experience on a swim team. Adolescent athletes were targeted, and all athletes were between the ages of 12-17 years, with a mean age of 14.1 ± 1.3 years. Height and weight were recorded, with a mean height of 168.9 ± 4.3 cm and a mean weight of 57.8 ± 10.9 kg.

Cognitive Assessments

Cognitive function was assessed using CogState computerized cognitive assessment software. Three CogState tasks were used to assess different aspects of cognitive function:

1. Two Back (TB) Task
    - Subject is shown a series of cards in a random order and asked to recall if the card shown currently is the same card presented two cards ago. TB Task is used to measure attention and working memory.
2. Groton Maze Learning (GML) Test
    - Subject is shown a 10x10 grid of tiles, and asked to find the correct passage through the hidden maze. Subject is alerted by a loud tone if a tile not on the path is chosen, and must return to the last correct tile in order to continue. GML Test measures executive function and spatial problem solving.
3. Continuous Paired Associate Learning (CPAL) Task
    - Subject is shown a yellow sphere surrounded by several different shapes. After a brief period, the shapes surrounding the yellow sphere are covered by blue spheres. Subject is shown a shape under the yellow sphere and must

remember which blue sphere hides that particular shape. CPAL Task measures visual learning and memory.

Subjects completed a “training” session prior to data collection. During the training session, subjects were exposed to CogState for the first time before testing began. Subjects used the training session to familiarize themselves with the CogState program and were able to ask any questions they had about how to navigate and complete the different tasks.

Conditions

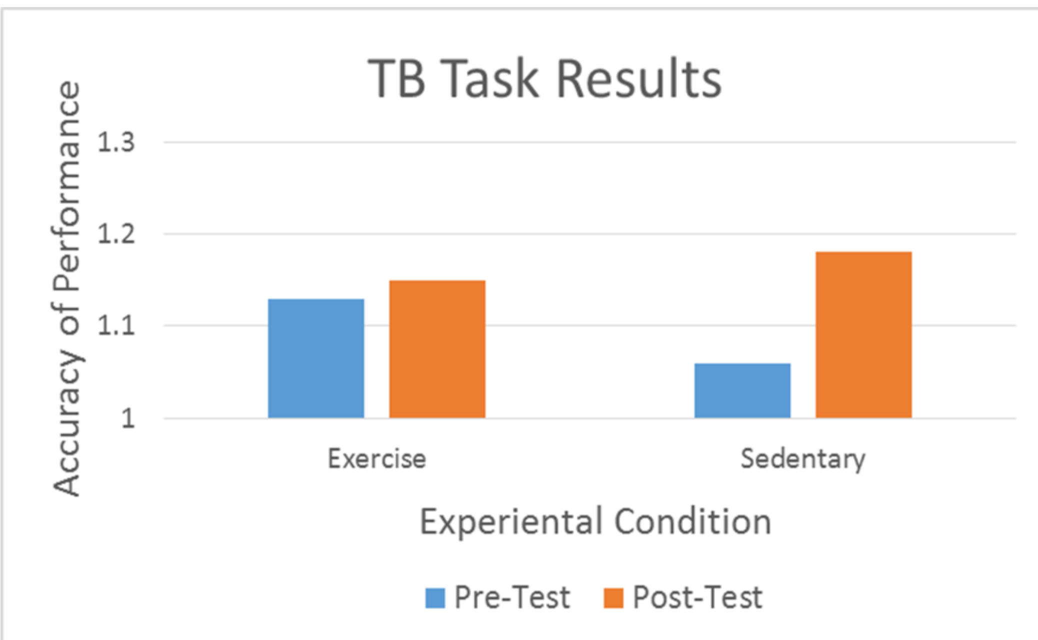
Two separate conditions were examined, an exercise condition and a sedentary condition. Subjects completed the CogState assessments a total of four times, both before and after each condition. The exercise condition consisted of an hour long moderate to vigorous intensity swim practice (Appendix C). The sedentary condition was an hour long seated viewing of an instructional swimming video. The video shown was Fast Lane Backstroke with Frank Busch (2006). Coach Busch is a three-time NCAA coach of the year with the University of Arizona Varsity Swimming and Diving program. This video consisted of a series of drills and tips for swimming the backstroke more efficiently. Subjects met in the Activity Promotion Laboratory at 6:10 AM. The pre-test assessments began at approximately 6:15 AM, with an estimated 15 minute completion time. Subjects were then randomly assigned to the exercise or sedentary condition. After completion of their assigned experimental condition, subjects were given a 10-minute break before completing the post-test assessments. Testing concluded after the second assessment was completed. Subjects returned two days later (i.e., If tested on Monday, second day of testing was Wednesday) and completed the same protocol, but were assigned to the condition they did not complete on the first day of testing. Four subjects were tested each day.

Results

Two Back Task

TB Task results were measured by accuracy of performance using the arcsine transformation for the square root of the proportion of correct responses (CogState, 2009). This arcsine proportion is the unit of measure. The exercise condition pre-test mean was 1.13 ± 0.29, with a post-test mean of 1.15 ± 0.31. The sedentary condition pre-test mean was 1.06 ± 0.25, with a post-test mean of 1.18 ± 0.25. These results are represented graphically in Figure 1 below. The associated effect size for the exercise condition was 0.05, while the effect size for the sedentary condition was found to be 0.49. These results indicated a borderline significant time x condition interaction (P=.06).

Figure 1: Two Back Task Results

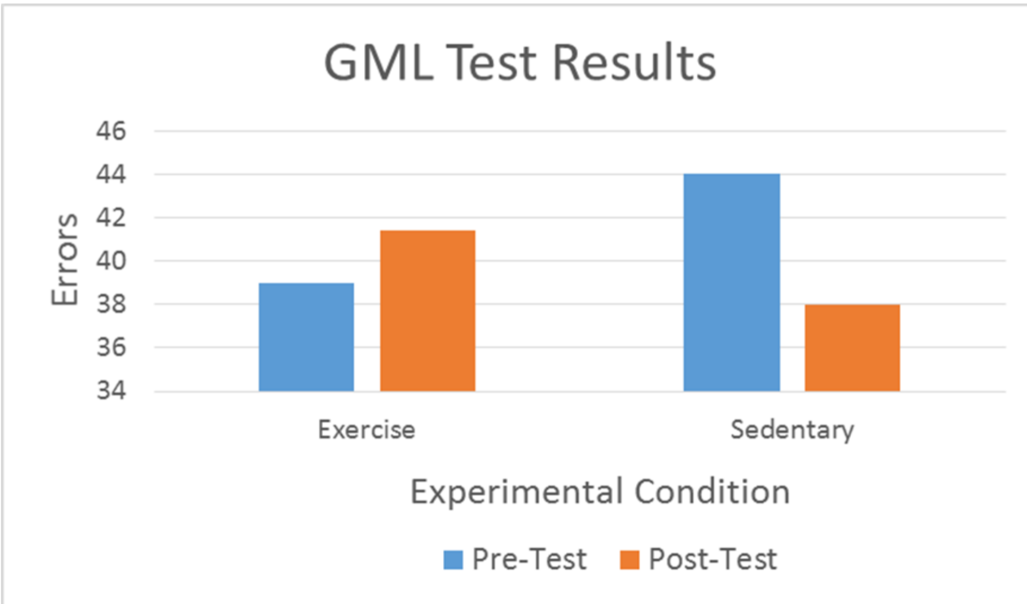


Groton Maze Learning Test

GML Test results were measured by the total number of correct moves made per second. Errors made was the unit of measure (CogState, 2009). The exercise condition pre-test mean was

39 ± 12, with a post-test mean of 41.1 ± 13.3. The sedentary condition pre-test mean was 44 ± 17.8, with a post-test mean of 38 ± 12.4. These results are displayed in Figure 2. The exercise condition had an effect size of -0.16. The sedentary condition had an effect size of 0.39. These results indicated a borderline significant interaction (P=.07).

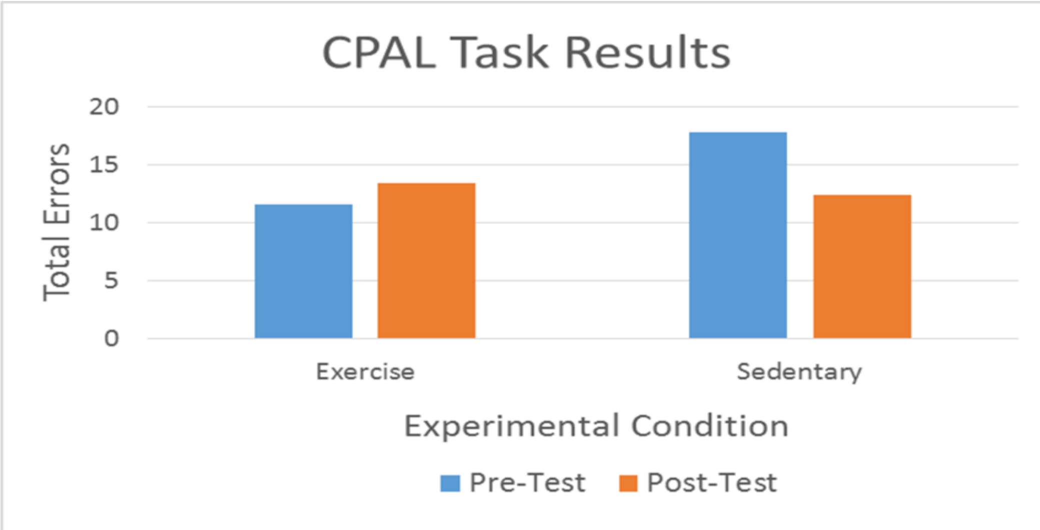
Figure 2: Groton Maze Learning Test Results



<u>Continuous Paired Associate Learning Task</u>

CPAL Task results were measured by accuracy of performance using the total number of errors across the five rounds. Total errors was the unit of measure (CogState, 2009). The exercise condition pre-test and post-test mean, shown below in Figure 3, were found to be 11.6 ± 6.9 and 13.4 ± 22.2 respectfully. The sedentary condition pre-test mean was 17.8 ± 15.4, with a post-test mean of 12.4 ± 11.6. The effect size for the exercise condition was 0.22. The sedentary condition effect size was 0.34. These results indicated no significant time x condition interaction (P=.30).

Figure 3: Continuous Paired Associate Learning Task Results



Discussion

Results for the exercise condition across all three cognitive measurements show that 60 minutes of moderate-to-vigorous exercise had no significant effects on the cognitive function measures used in this study. These results were unexpected. Based on previous research, we expected small improvements in cognitive function subsequent to exercise (Chang; et al., 2012).). A possible explanation could be the cognitive and physical demands of the swim practice leads to fatigue after the practice. The cognitive and physical loads of the swim practice could potentially fatigue the athletes to the point where no cognitive improvements were observed directly following physical activity. Another potential cause of these results could be low glucose levels. Several studies have shown that providing a small glucose snack before performing cognitive tasks boost results (Riby, 2004; Scholey et al., 2013). While glucose levels were not measured in this particular study, it would be plausible that after sleep and exercise that the subjects' glucose levels were low.

Results for the sedentary condition showed small to medium improvements in cognitive function across all three cognitive tasks. It is possible that the instructional nature of the swim video may account for increases in several aspects of cognitive function subsequent to the sedentary control condition. Subjects could have been actively engaging with the instructional material and cognitively applying the drills and tips offered in the video to their own strokes.

Future Studies

Several adjustments could be made to further study the relationship between adolescent athletes and cognitive function. A larger sample size would yield more generalizable results. The study could further be expanded to include athletes from other sports (e.g., track and field, football, baseball). It would be interesting to compare the effects of different types of activities on cognitive function. Exercise conducted on treadmills and cycle ergometers could affect the cognitive function differently when compared to exercise through group sport, individual sport or recess. If group sport or recess shows to increase cognitive function, this could influence teachers' scheduling of testing times in order to maximize students' cognitive function.

Another possible area of interest would be to look at the relationship between exercise and cognitive function in college aged students, specifically collegiate athletes. Collegiate athletes are notorious for practicing at all times of day, especially in the morning before they attend their classes. Studying the effects of exercise on cognitive function in adult athletes would further help explore the effect of exercise on brain function and would help collegiate athletes optimize their classroom performance.

It is well documented that acute exercise has small improvements on cognitive function in adolescents (Chang; et al., 2012). Our results did not align with these expectations. Based on the data collected, early morning exercise has no significant effect on cognitive function in adolescent athletes. It appears that the mode of exercise may affect the impact on cognitive performance. We would also recommend a longer waiting period, around 20 minutes, before cognitive assessments are measured in future studies. Further research is recommended to explore this claim.

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Appendix

Appendix A: IRB Approval

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
4N-70 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** · **www.ecu.edu/irb**

Notification of Initial Approval: Expedited

From:	Social/Behavioral IRB
To:	Aaron Parker
CC:	Matthew Mahar
Date:	5/6/2015
Re:	UMCIRB 15-000256 Effects of an Acute Bout of Exercise on Cognitive Function in Adolescent Athletes

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) is for the period of 5/5/2015 to 5/4/2016. The research study is eligible for review under expedited category # 4, 6, 7. The Chairperson (or designee) deemed this study no more than minimal risk.

Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

Name	Description
Assent Form Swimming and Cognitive Function.doc	Consent Forms
Parental Consent Form Swimming and Cognitive Function.doc	Consent Forms
Participation Flyer Swimming and Cognitive Function.doc	Recruitment Documents/Scripts
Senior Honors Project Thesis	Study Protocol or Grant Application

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

Appendix B: Recruitment Flyer

Research Study Participants Needed

***Title of Study:* Effects of an Acute Bout of Exercise on Cognitive Function in Adolescents**

Participants Needed:

- 10 Boys and 10 Girls Ages 12-17

Overview of Study:

- The children will participate in cognitive function tests before and after their normally scheduled swim practice. The children will also take these tests before and after a sedentary activity, such as watching television.

Participant incentives:

- Participants will receive a $10 gift card for their participation.

Appointments:

- Tests will take approximately 15 minutes, and will be taken directly before and after the normally scheduled swim practice.

If interested, please contact **AJ Parker (parkera12@students.ecu.edu)**, Activity Promotion Lab, Department of Kinesiology, East Carolina University, Greenville, NC 27858 at 252-902-6249.

Appendix C: Swim Practice

Exercise Condition- Swim Practice

Swam in 25 Yard Pool at Minges Natatorium

Warm Up

300 - 4:00, Swim
200 - 4:00, Kick
100 - 2:00, Choice

Pre Set

9 x 50 - 3 @ 1:00, 3 @ :55, 3 @ :50, Kick
3 x 100 - 1:45, Kick

Main Set

3 x

3 x 50 - 1:00, 1- Kick/Drill, 2- Drill/Swim, 3- Perfect
4 x 25 - :30, Variable Sprint, 1- Build, 2- Breakout, 3- Fast, 4- Easy
1 x Broken 200 - 3:00, Fast Freestyle
    1 x 75 - 10 seconds rest
    1 x 50 - 10 seconds rest
    1 x 75

Warm Down

3 x 50 - 1:00, Easy Swim
6 x 25 - :45, Easy Kick
1 x 100 - 2:00, Easy Choice

Total Time: 57 Minutes
Total Yardage: 3050 yards